of the gas the oxygen was withdrawn by ignited phosphorus, and no visible residue was left. When, however, another gas was introduced, so as to come into contact with the top of the tube, and then withdrawn, the emanation was found to be present in it in unaltered amount. It appears, therefore, that phosphorus burning in oxygen and sparking with oxygen have no effect upon the gas so far as can be detected by its radio-active properties.

The experiments with magnesium-lime were more strictly quantitative. The method of testing the gas before and after treatment with the reagent was to take 1/2000th part of the whole mixed with air, and after introducing it into the reservoir of an electroscope to measure the rate of discharge. The magnesium-lime tube glowed brightly when the mixture of emanation and air was admitted, and it was maintained at a red-heat for three hours. The gas was then washed out with a little hydrogen, diluted with air and tested as before. It was found that the discharging power of the gas had been quite unaltered by this treatment.

The emanation can be dealt with as a gas; it can be extracted by aid of a Töpler pump; it can be condensed in a U-tube surrounded by liquid air; and when condensed it can be "washed" with another gas which can be pumped off completely, and which then possesses no luminosity and practically no discharging power. The passage of the emanation from place to place through glass tubes can be followed by the eye in a darkened room. On opening a stopcock between a tube containing the emanation and the pump, the slow flow through the capillary tube can be noticed; the rapid passage along the wider tubes; the delay caused by the plug of phosphorus pentoxide, and the sudden diffusion into the reservoir of the pump. When compressed, the luminosity increased, and when the small bubble was expelled through the capillary it was exceedingly luminous. The peculiarities of the excited activity left behind on the glass by the emanation could also be well observed. When the emanation had been left a short time in contact with the glass, the excited activity lasts only for a short time; but after the emanation has been stored a long time the excited activity decays more slowly.

The emanation causes chemical change in a similar manner to the salts of radium themselves. The emanation pumped off from 50 milligrams of radium bromide after dissolving in water, when stored with oxygen in a small glass tube over mercury turns the glass distinctly violet in a single night; if moist the mercury becomes covered with a film of the red oxide, but if dry it appears to remain unattacked. A mixture of the emanation with oxygen produces carbon dioxide when passed through a lubricated stopcock.

(3) *Occurrence of Helium in the Gases Evolved from Radium Bromide.*

The gas evolved from 20 milligrams of pure radium bromide (which we are informed had been prepared three months) by its solution in water and which consisted mainly of hydrogen and oxygen (*cf.* Giesel, *Ber.*, 1903, 347) was tested for helium, the hydrogen and oxygen being removed by contact with a red-hot spiral of copper wire, partially oxidised, and the resulting water vapour by a tube of phosphorus pentoxide. The gas issued into a small vacuum-tube which showed the spectrum of carbon dioxide. The vacuum tube was in train with a small U-tube, and the latter was then cooled with liquid air. This much reduced the brilliancy of the CO_2 spectrum, and the D_3 line of helium appeared. The coincidence was confirmed by throwing the spectrum of helium into the spectroscope through the comparison prism, and shown to be at least within 0·5 of an Ångström unit.

The experiment was carefully repeated in apparatus constructed of previously unused glass with 30 milligrams of radium bromide, probably four or five months old, kindly lent us by Prof. Rutherford. The gases evolved were passed through a cooled U-tube on their way to the vacuum-tube, which completely prevented the passage of carbon dioxide and the emanation. The spectrum of helium was obtained and practically all the lines were seen, including those at 6677, 5876, 5016, 4932, 4713, and 4472. There were also present three lines of approximate wave-lengths, 6180, 5695, 5455, that have not yet been identified.

On two subsequent occasions the gases evolved from both solutions of radium bromide were mixed, after four days' accumulation which amounted to about 2·5 c.c. in each case, and were examined in a similar way. The D_3 line of helium could not be detected. It may be well to state the composition found for the gases continuously generated by a solution of radium, for it seemed likely that the large excess of hydrogen over the composition required to form water, shown in the analysis given by Bodländer (*Ber., loc. cit.*) might be due to the greater solubility of the oxygen. In our analyses the gases were extracted with the pump, and the first gave 28·6, the second 29·2 per cent. of oxygen. The slight excess of hydrogen is doubtless due to the action of the oxygen on the grease of the stopcocks, which has been already mentioned. The rate of production of these gases is about 0·5 c.c. per day for 50 milligrams of radium bromide, which is more than twice as great as that found by Bodländer.

(4) *Production of Helium by the Radium Emanation.*

The maximum amount of the emanation obtained from 50 milligrams of radium bromide was conveyed by means of oxygen into a U-tube cooled in liquid air, and the latter was then extracted by the pump. It was then washed out with a little fresh oxygen, which was again pumped off. The vacuum tube sealed on to the U-tube, after removing the liquid air, showed no trace of helium. The spectrum was apparently a new one, probably that of the emanation, but this has not yet been completely examined, and we hope to publish further details shortly. After standing from July 17 to 21, the helium spectrum appeared, and the characteristic lines were observed identical in position with those of a helium tube thrown into the field of vision at the same time. On July 22 the yellow, the green, the two blues and the violet were seen, and in addition the three new lines also present in the helium obtained from radium. A confirmatory experiment gave identical results.

We wish to express our indebtedness to the research fund of the Chemical Society for a part of the radium used in this investigation.

ON THE INTENSELY PENETRATING RAYS OF RADIUM.[1]

RADIUM is known to emit three types of radiation. These are:—

(1) The α rays, very easily absorbed by solids, and carrying a positive electric charge.

(2) The β rays, more penetrating than these, and negatively charged.

(3) The γ rays, intensely penetrating, and not conveying an electric charge at all.

In a paper published in the *Phil. Trans.* for 1901, I investigated the relative ionisations of gases by the α and β rays. The present communication may be regarded as a sequel to that one, and deals with the γ rays.

The radium employed was of activity 1000 (uranium = 1), and was contained in a glass cell, over which was cemented a piece of thin aluminium. The cell was placed in a cavity in a block of lead, and over it was placed a disc of lead 1 cm. in thickness. This it was considered would suffice to suppress all but the γ rays, which are much the most penetrating.

In measuring the electrical leakage, the electroscope method was employed. The apparatus was that described in a paper published in the *Philosophical Magazine* for June, p. 681.

The radium, covered by the thick lead, was placed under the apparatus, and the rate of leak determined when the different gases filled the testing vessel.

The conditions were, of course, arranged so as to use a saturating E.M.F. The γ rays are so penetrating that there can be no question of their being appreciably absorbed in a moderate thickness of gas.

For the methods of preparation of the gases I must refer to the former paper (*Phil. Trans.*, A., vol. cxcvi., 1901, p. 508).

[1] By Hon. R. J. Strutt, Fellow of Trinity College, Cambridge. Communicated to the Royal Society by Lord Rayleigh, F.R.S. Received August 5.

The results were as follows; the rates of leak are given in scale divisions per hour, and are corrected to 30 inches pressure:—

Gas	Rate of Leak	Mean
Hydrogen	10·4, 10·5, 10·4, 11·2, 10·4, 11·2, 9·86, 10·1, 10·2 ...	10·5
Air	65·2, 66·6, 66·6, 60·0, 57·0, 61·5, 60·2, 63·0, 58·2, 58·3, 56·6, 56·2	62·1
Oxygen	75·0, 74·2, 71·0, 74·1	73·6
Carbon dioxide	96·0, 95·4, 94·5, 95·1, 94·1, 94·7	95·0
Cyanogen	107, 104, 106, 106	106·0
Sulphur dioxide... ...	132, 126, 134, 135	132·0
Chloroform	297, 298, 290, 327	303·0
Methyl iodide	298, 292, 310, 291	298·0
Carbon tetrachloride ..	363, 351, 344, 349	352·0

The following table gives the relative ionisations, referred to air as unity. The values of the same constants for the α and β rays formerly found are included, and also measurements of relative ionisation under Röntgen rays. These latter form part of an investigation not hitherto published.

Relative Ionisations.

Gas	Relative density	Relative Ionisation			
		α rays	β rays	γ rays	Röntgen rays
Hydrogen	0·0693	0·226	0·157	0·169	0·114
Air	1·00	1·00	1·00	1·00	1·00
Oxygen	1·11	1·16	1·21	1·17	1·39
Carbon dioxide	1·53	1·54	1·57	1·53	1·60
Cyanogen	1·86	1·94	1·86	1·71	1·05
Sulphur dioxide	2·19	2·04	2·31	2·13	7·97
Chloroform	4·32	4·44	4·89	4·88	31·9
Methyl iodide	5·05	3·51	5·18	4·80	72·0
Carbon tetrachloride ...	5·31	5·34	5·83	5·67	45·3

The determinations for the γ rays are less accurate than the former ones for the α and β rays, on account of the very much smaller rates of leak which have to be measured. I think, if this be taken into account, there is no reason to doubt that, within the limits of experimental error, the γ rays give the same values as the β rays. These values are nearly proportional to the density of the gas, except in the case of hydrogen. The law which holds in the case of Röntgen rays is totally different.

This conclusion throws some light on the nature of the β rays. The view seems to be gaining ground that these are Röntgen rays, produced by the impact of the β rays on the radium itself.[1] This theory seems to have much to recommend it. The β rays should, by analogy with the kathode rays in a vacuum tube, produce Röntgen rays when they strike a solid obstacle, and these Röntgen rays should be much more penetrating than the β rays themselves. The γ rays seem at first sight to be just what should be expected. But the present paper shows that in one respect, at all events, the γ rays behave quite differently from Röntgen rays, while, on the other hand, they resemble the α and β rays. There seems to be a possibility that they too are of a corpuscular nature, though uncharged with electricity. This would account for the absence of magnetic deflection.

I do not think that the absence of conspicuous Röntgen radiation is very hard to understand, if we consider that the current emitted in kathode rays by a square inch of intensely active radium is only 10^{-11} amperes; the current through a focus tube is of the order 10^{-2} amperes, and probably a great part of this is carried by the kathode rays.

[1] See, for instance, Madame Curie, "Thèses presentées à la Faculté des Sciences," 1903, p. 83.

THE COLORATION OF THE QUAGGAS.

It is well known that, in different districts of their range, the zebras of the type commonly known as Burchell's, but which, for reasons elsewhere given, I propose to call "quaggas," present distinct and easily determinable colour variations, sufficiently constant in character to be worthy of nominal recognition. Grant's quagga occurs in North-East Africa, Crawshay's quagga in Nyasaland, Selous's quagga in Rhodesia, and Chapman's quagga in Angola. Still further south came Burchell's quagga, and south of this again the two or more extinct types which, as Mr. Lydekker has shown, pass currently as the quagga proper.

The first and last of this category are the extremes in pattern variation. Grant's quagga may claim to rank as one of the most completely striped of existing horses. Apart from the ears, which are sometimes nearly white, and the muzzle and fetlocks, which are usually black, he is a mass of stripes from head to tail, from hoof to spine; and in sharpness of contrast between the blackness of the stripes and the whiteness of the interspaces, he rivals the Abyssinian race of Grévy's zebra and the Angolan race of the mountain species, while surpassing both in the inferior extension of the stripes to the middle line of the belly. Place him alongside Gray's quagga, with his pale stripeless limbs, underside and hind-quarters, his brown and confusedly banded body and fawn-lined neck and head, and you will hardly believe them to be the same species. Yet there is no avoidance of the conclusion, since all intermediates have been seen either as living specimens or mounted skins. And one of the chief interests centred in the existence of these intermediates lies in the progressiveness of the change this species undergoes as it passes from north to south over its geographical area. Even in British and German East Africa the pale interspaces on Grant's quagga begin to be washed with brown, and to be filled in with narrower intervening stripes. It will be difficult, perhaps impossible, to distinguish such forms from the quagga of the Mashonaland plateau. The latter, indeed, may be taken as illustrative of the first step in the change above alluded to leading from Grant's to Gray's quagga. From it may be traced a series of gradations represented by the local races named after Chapman, Wahlberg, and Burchell, in which the stripes gradually disappear and thin out upwards from the fetlocks to the shoulders and haunches, while those on the body lose their connection with the mid-ventral band, and, becoming shorter, leave the belly unstriped. Concomitantly the intervening "shadow" stripes increase in number and definition as they extend forwards towards the neck, the normal stripes themselves turn brown, and the ochre-stained ground colour deepens in hue. In the typical form of Burchell's quagga the "shadow" stripes reach the head, and the last of the complete stripes is the one that extends backwards from the stifle to the root of the tail, the hind-quarters and legs being practically, and the belly actually, stripeless. It is but a step from this to the extinct Gray's quagga, in which the stripes of the body were fused together and blended to a great extent with the brown of the intervening areas, those on the neck being exceedingly broad and broken up by paler tracts of hair.

The tendency of these modifications is to convert a striped and conspicuously parti-coloured animal into one which, even at a short distance, must have appeared to be an almost uniform brown, paling into cream on the underside, limbs and back of the haunches. What is the meaning of this change? Inferentially we may conclude it was protective in the sense of subserving concealment.

The testimony of observers in the field has established the truth that the coloration of the coat renders a zebra invisible under three conditions, namely, at a distance on the open plain in midday, at close quarters in the dusk and on moonlit nights, and in the cover afforded by thickets. The procryptic result is achieved by the cooperation of several factors. The white stripes blend with the shafts of light sifted through the foliage and branches and reflected by the leaves of the trees, and in an uncertain light or at long range they mutually counteract each other and fuse to a uniform grey. It is probable, too, that the alternate arrangement of the black and white bars contributes something to the effect produced, by imparting a blurred appear-